

Fusion Energy Sciences Perspective

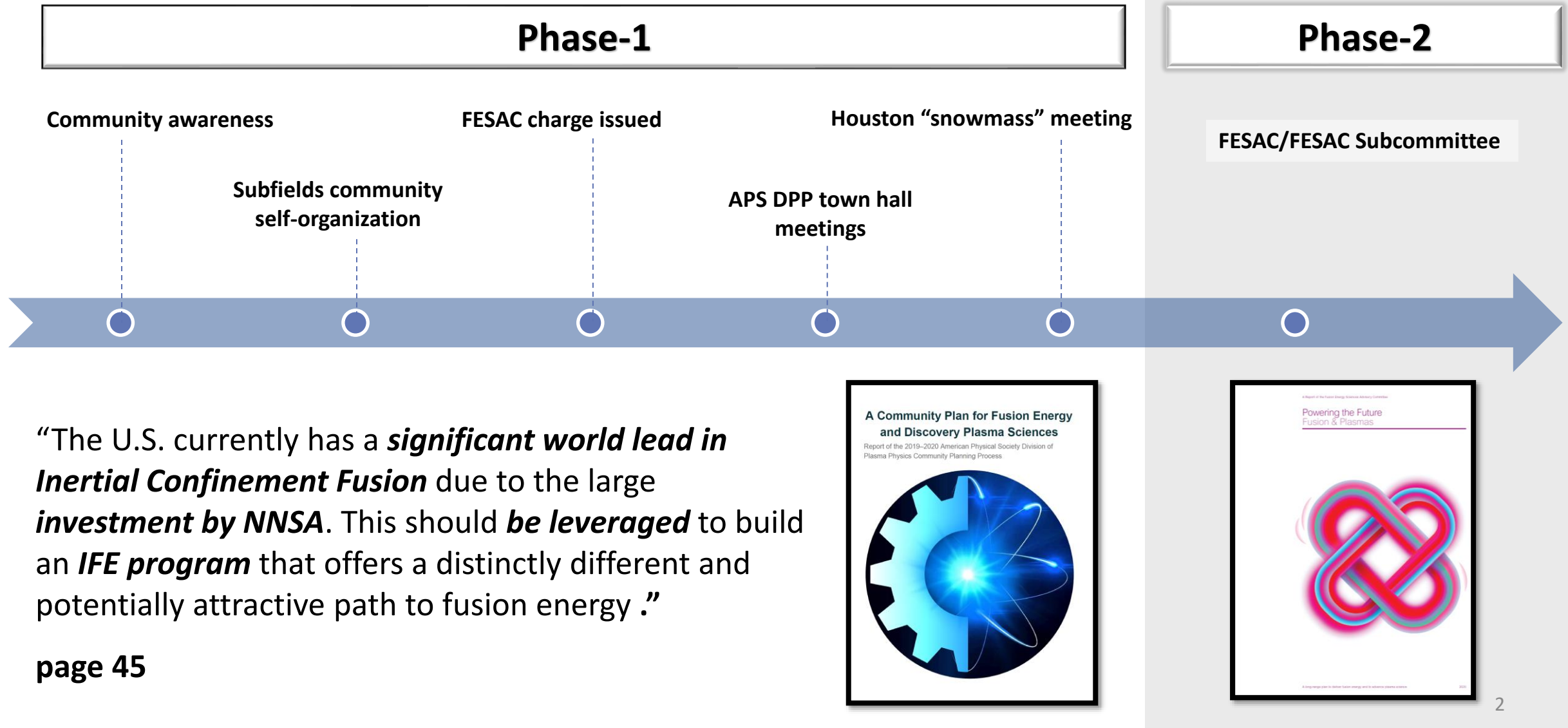
Kramer U. Akli
Program Manager
Fusion Energy Sciences
DOE Office of Science

IFE Science & Technology Community Strategic Planning Workshop, February 22 - 24, 2022

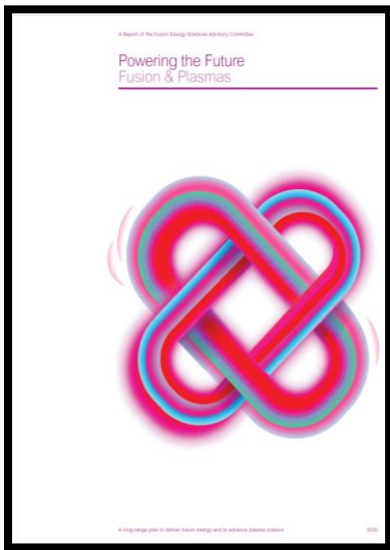


U.S. DEPARTMENT OF
ENERGY

Long-range strategic planning activities



Powering the Future: Fusion & Plasmas

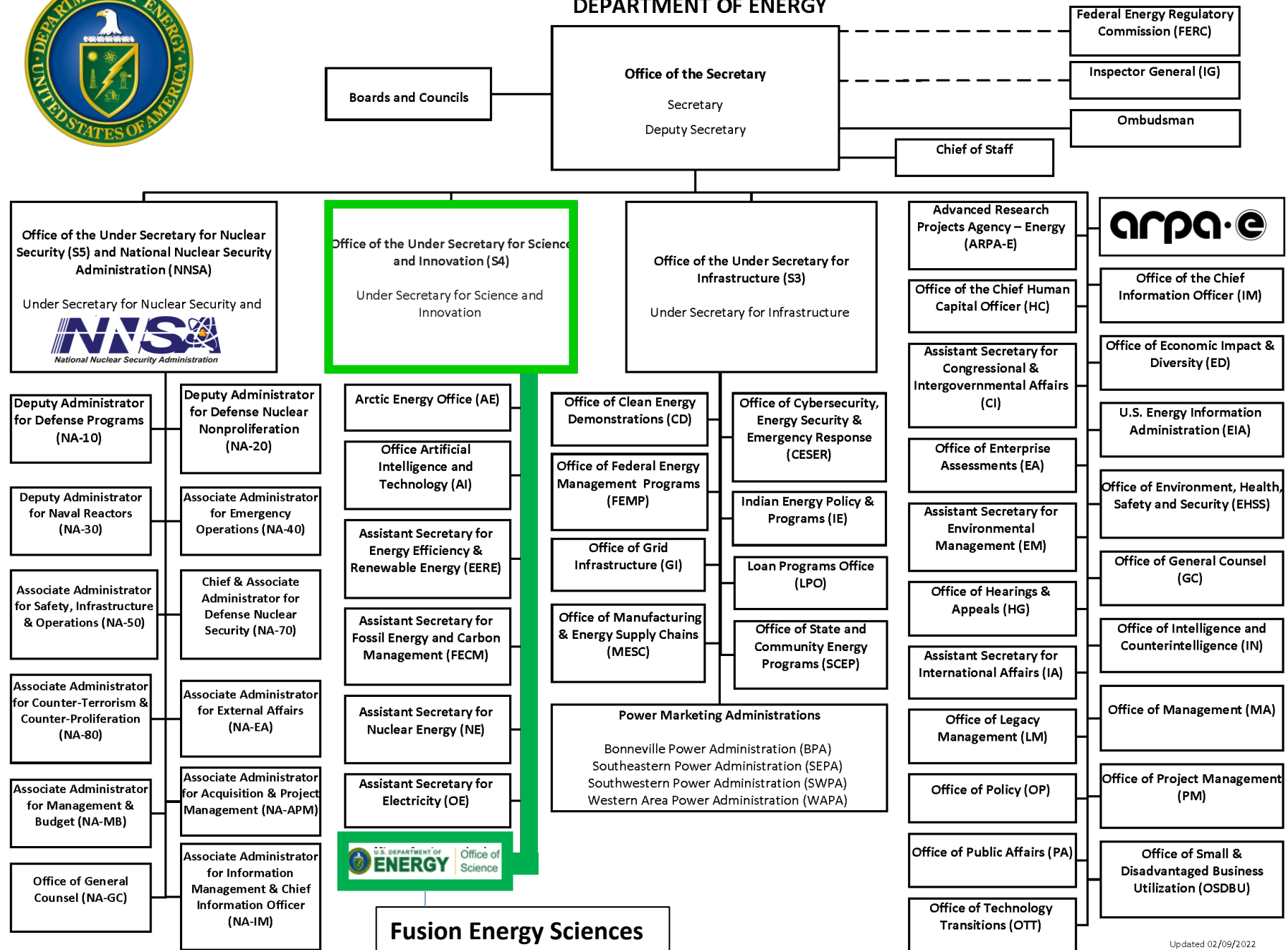


Portfolio Elements	Scenarios			Technology and Science Drivers				
	Constant Level of Effort Significant loss of US leadership & significant missed opportunities	Modest Growth Loss of US leadership & missed opportunities	Unconstrained	Sustain a Burning Plasma	Engineer for Extreme Conditions	Harness Fusion Power	Strengthen the Foundations	Create Transformative Technologies
Research, Operations, and Small Scale Construction								
FM&T Programs	Yes, enhance	Yes, enhance	Yes, enhance	•	•	•		•
US Tokamak Operations and Research	Yes, but reduce	Yes, but reduce	Yes	•	•		•	
Stellarator and Alternates Operations and Research	Yes, but flat	Yes	Yes, enhance	•	•		•	
IFE program	Yes, but limited	Yes, but limited	Yes	•				

“An IFE program that leverages US leadership and current investments should be targeted.”



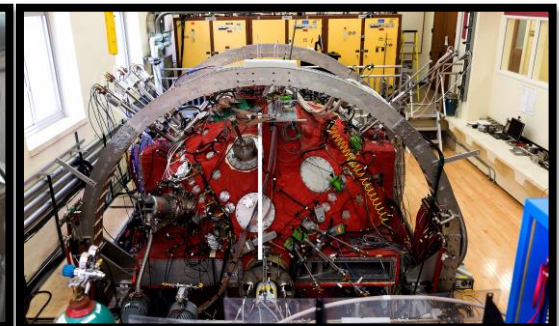
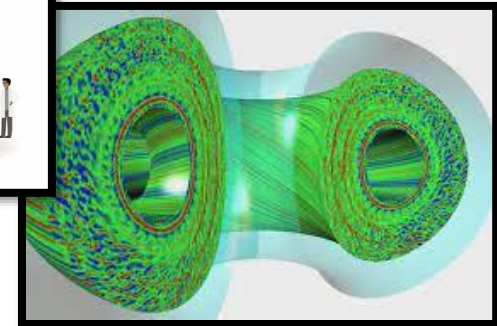
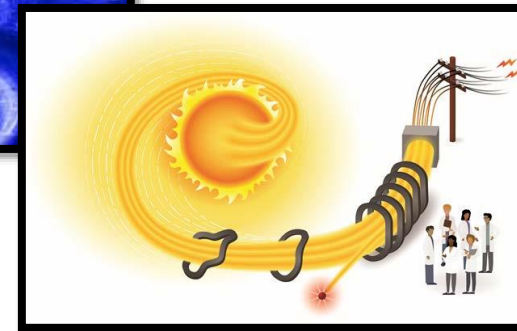
DEPARTMENT OF ENERGY



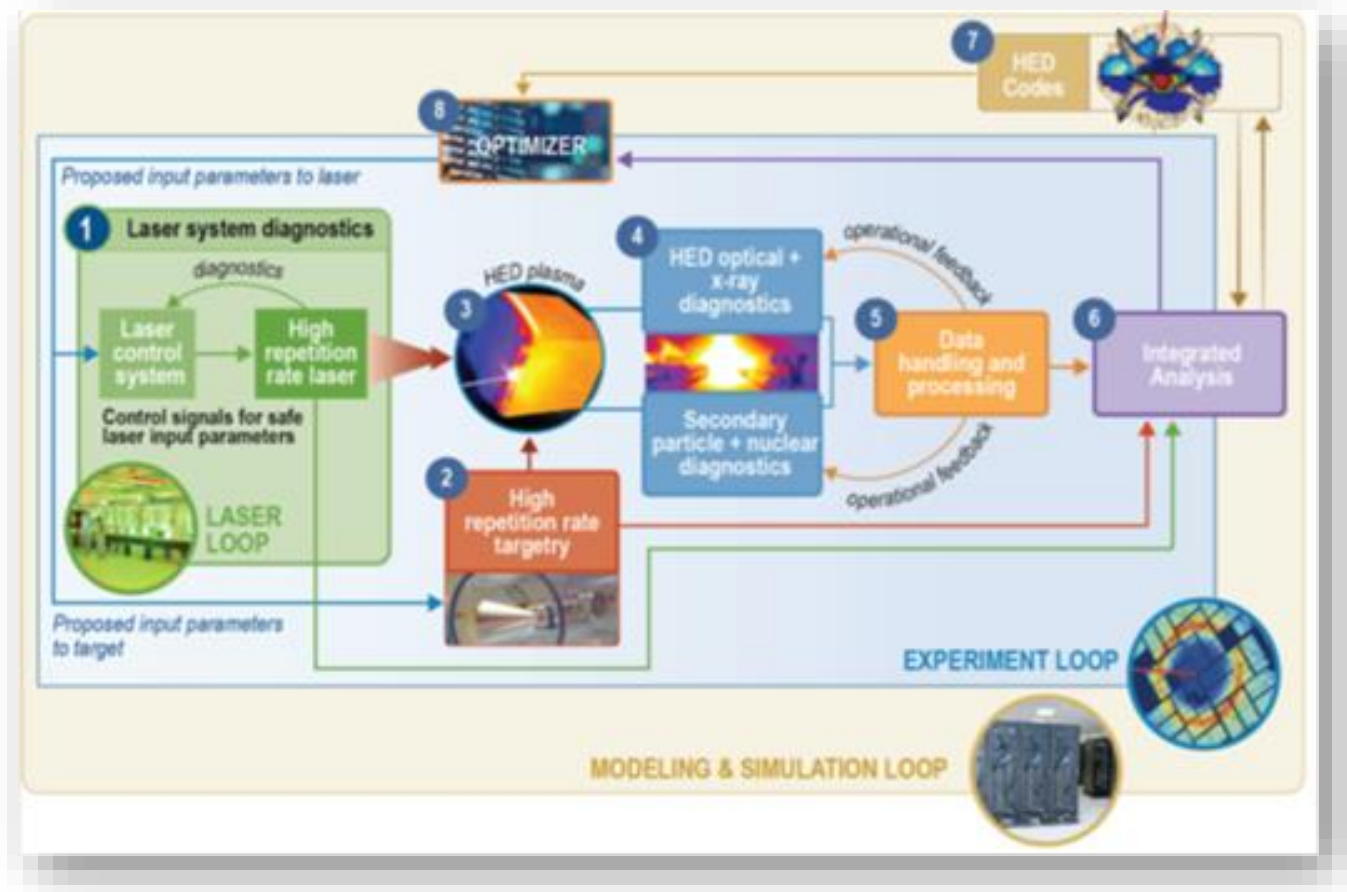
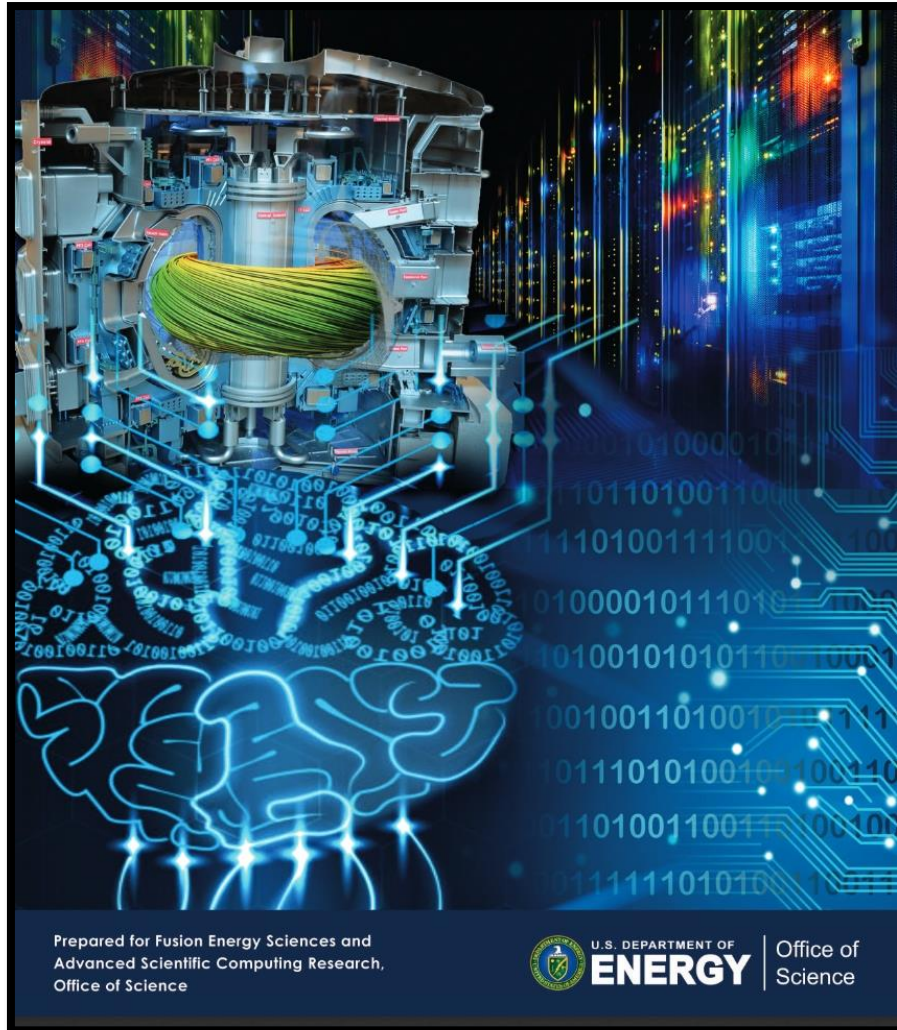


FES Mission

- To build the knowledge needed to develop a fusion energy source
 - Advanced & Spherical Tokamaks
 - Theory & Simulation
 - Materials & Fusion Nuclear Science
 - Public-Private Partnerships
 - **IFE (recommended by FESAC LRP)**
- To expand the understanding of matter at very high temperatures and densities
 - High Energy Density Laboratory Plasmas (HEDLP)
 - General Plasma Science (GPS)
 - QIS, Measurement Innovation, ...



Advancing Fusion with Machine Learning BRN Report



IFE must take advantage of AI/ML research

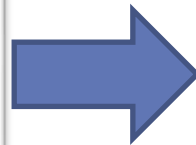


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The Joint Program in High Energy Density Laboratory Plasmas



Main Topics:

1. High energy density (HED) hydrodynamics
2. Nonlinear optics of plasmas
3. Relativistic HED plasma and intense beam physics
4. Magnetized HED plasma physics
5. Radiation-dominated dynamics and material properties
6. Warm dense matter

Additional cross-cutting topics:

1. *Computing*
2. *Diagnostics*
3. *Research infrastructure*
4. *High-Z multiply ionized HED atomic physics.*

The Joint Program is not an IFE Program



FINANCIAL ASSISTANCE
FUNDING OPPORTUNITY ANNOUNCEMENT



ADVANCED RESEARCH PROJECTS AGENCY – ENERGY (ARPA-E)
U.S. DEPARTMENT OF ENERGY

**BREAKTHROUGHS ENABLING THERMONUCLEAR-FUSION
ENERGY (BETHE)**

Announcement Type: Initial Announcement
Funding Opportunity No. DE-FOA-0002212
CFDA Number 81.135

Funding Opportunity Announcement (FOA) Issue Date:	Thursday, November 7, 2019
Deadline for Questions to ARPA-E-CO@hq.doe.gov :	5 PM ET, Friday, January 3, 2020
Submission Deadline for Full Applications:	9:30 AM ET, Tuesday, January 14, 2020
Submission Deadline for Replies to Reviewer Comments:	5 PM ET, Friday, February 28, 2020
Expected Date for Selection Notifications:	April 2020
Total Amount to Be Awarded	Approximately \$30 million, subject to the availability of appropriated funds.
Anticipated Awards	ARPA-E may issue one, multiple, or no awards under this FOA. Awards may vary between \$150,000 and \$10 million, not including cost share.

- For eligibility criteria, see Section III.A of the FOA.
- For cost share requirements under this FOA, see Section III.B of the FOA.
- To apply to this FOA, Applicants must register with and submit application materials through ARPA-E eXCHANGE (<https://arpa-e-foa.energy.gov/Registration.aspx>). For detailed guidance on using ARPA-E eXCHANGE, see Section IV.G.1 of the FOA.
- Applicants are responsible for meeting each submission deadline. Applicants are strongly encouraged to submit their applications at least 48 hours in advance of the submission deadline.
- For detailed guidance on compliance and responsiveness criteria, see Sections III.C.1 through III.C.4 of the FOA.

FES and ARPA-E funded fusion projects

- Breakthroughs Enabling Thermonuclear-fusion Energy (BETHE)
- Galvanizing Advances in Market-aligned fusion for an Overabundance of Watts (GAMOW)

Broadband Frequency
Conversion of Spectrally
Incoherent Pulses

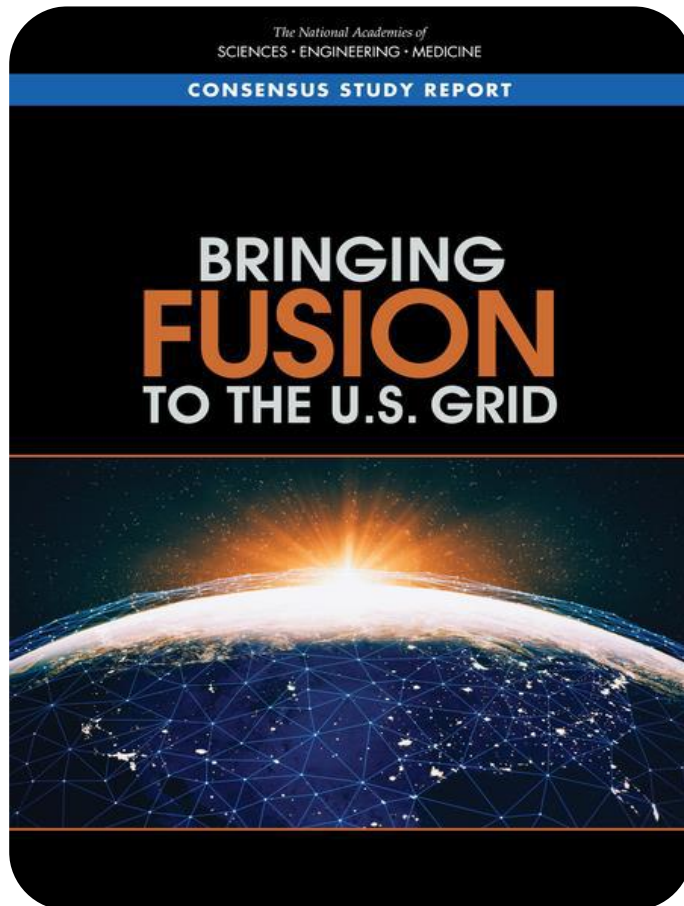
Argon Fluoride laser as an
enabler for low-cost inertial
fusion energy

IFE drivers

FES will continue to partner with ARPA-E in fusion areas of common interest



Recent NASEM Report: Bringing Fusion to the U.S. Grid



Bringing Fusion to the U.S. Grid: Key Goals and Innovations for a U.S. Fusion Pilot Plant (2021)

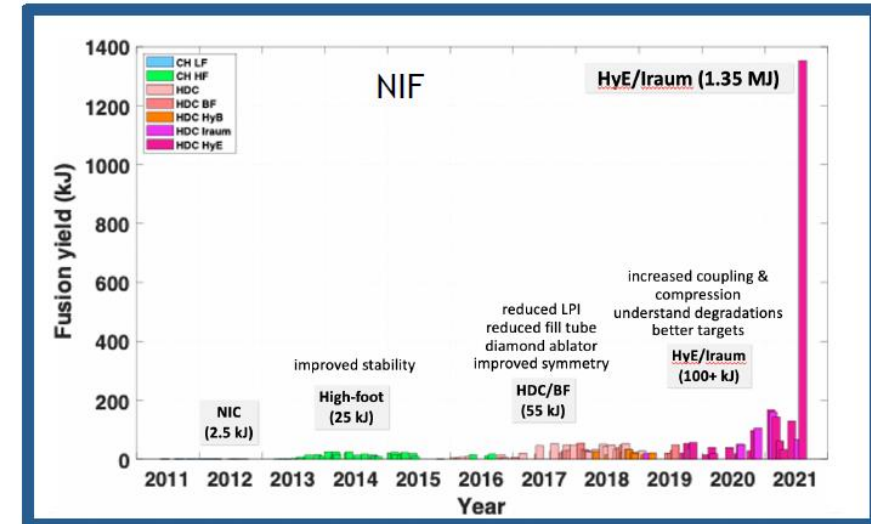
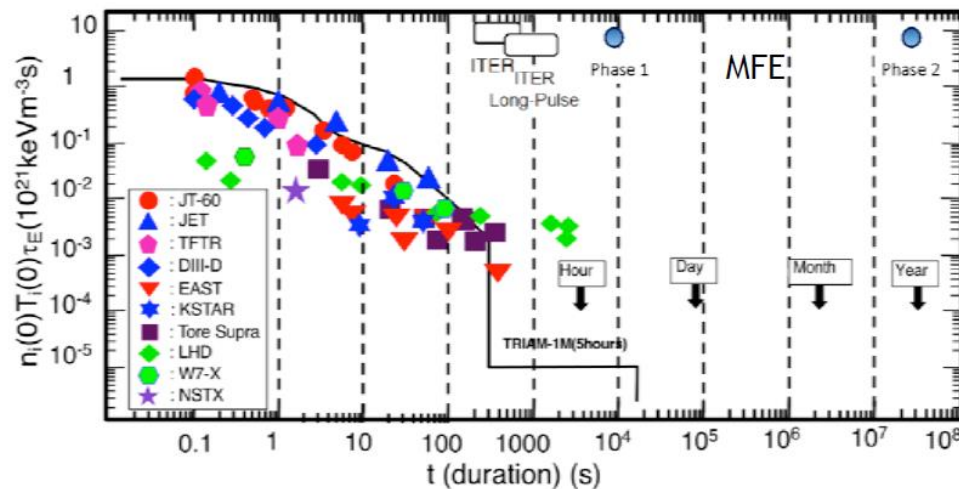
- To make an impact on the transition to a low-carbon emission electrical system by **2050**, the **Department of Energy** and the **private sector** should **produce net electricity in a fusion pilot plant** in the United States in the **2035—2040** timeframe.
- DOE should move forward now to foster the creation of national teams, including public-private partnerships, that **will develop conceptual pilot plant designs and technology roadmaps** that will lead to an engineering design of a pilot plant that will bring fusion to commercial viability.

An IFE program should be aware of the developments in MFE.

- Leverage
- Avoid duplication

Innovation and Research in Fusion Plasma Confinement

The pilot plant design will need to be based on a vetted, well-established confinement physics basis for achieving net plasma gain well in excess of unity.



Both MFE and ICF (NIF) have achieved energy gain ~ 0.7 relative to heating power to the plasma

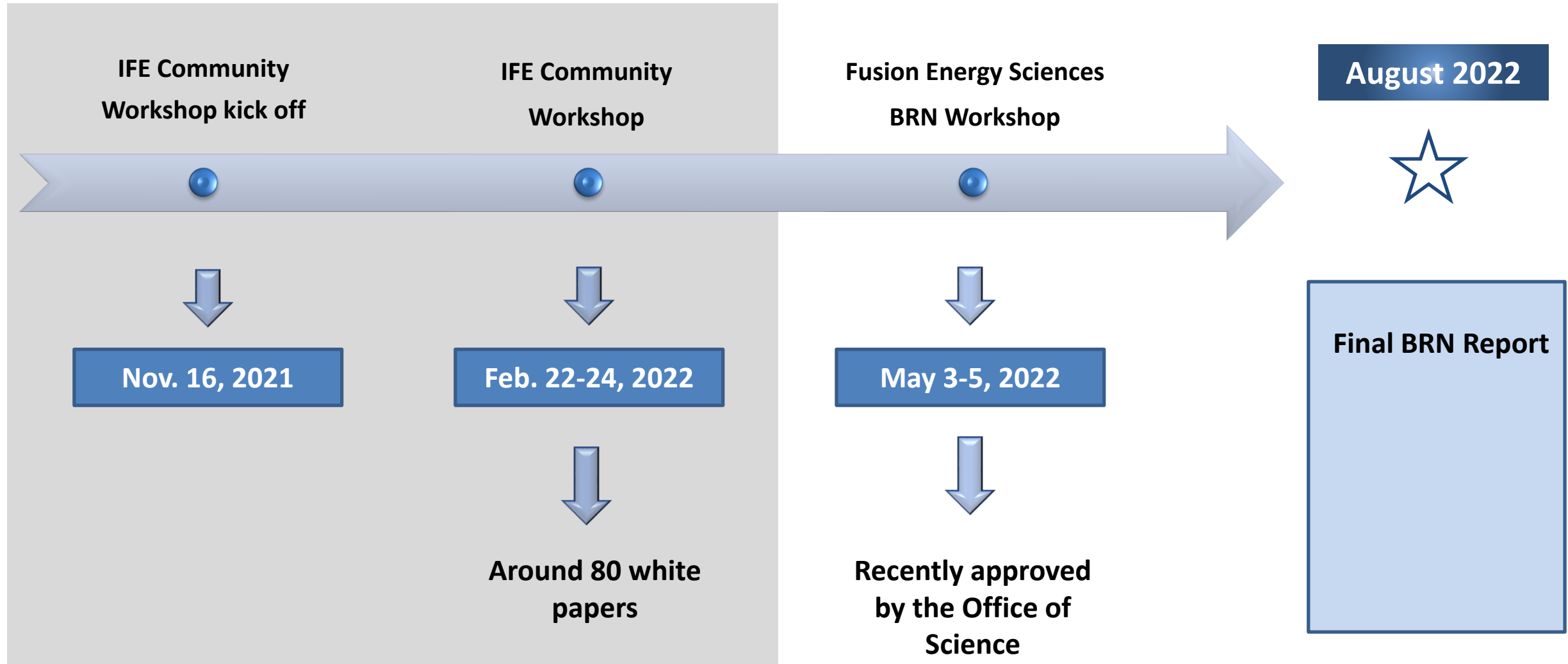
Computer simulations coupled to experiment are driving performance improvement and design

Does IFE have a well-established confinement physics basis for a pilot plant design consideration?

A dramatic space-themed background. In the upper right, a large satellite with multiple solar panel arrays is visible. In the lower right, a rocket or spacecraft is shown in profile, moving towards the left. The background is a deep blue space filled with stars and streaks of light, suggesting high-speed travel or a dynamic environment. The overall color palette is dominated by blues, purples, and reds.

THE THRESHOLD OF IGNITION

Community Workshop & IFE BRN



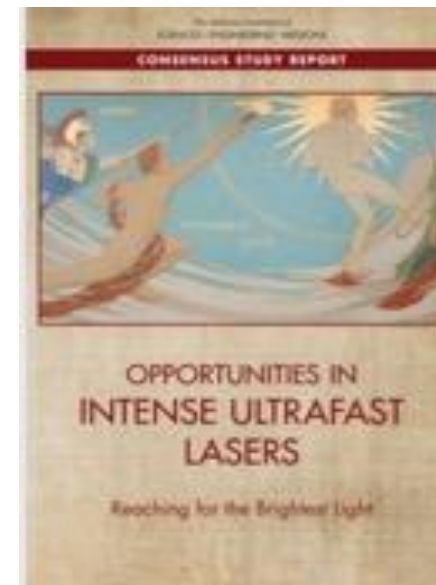


IFE Basic Research Needs Workshop Charge (1)

- Assess and summarize the status of science and technology in Inertial Fusion Energy (IFE) in the U.S. and abroad.



IFE Specific

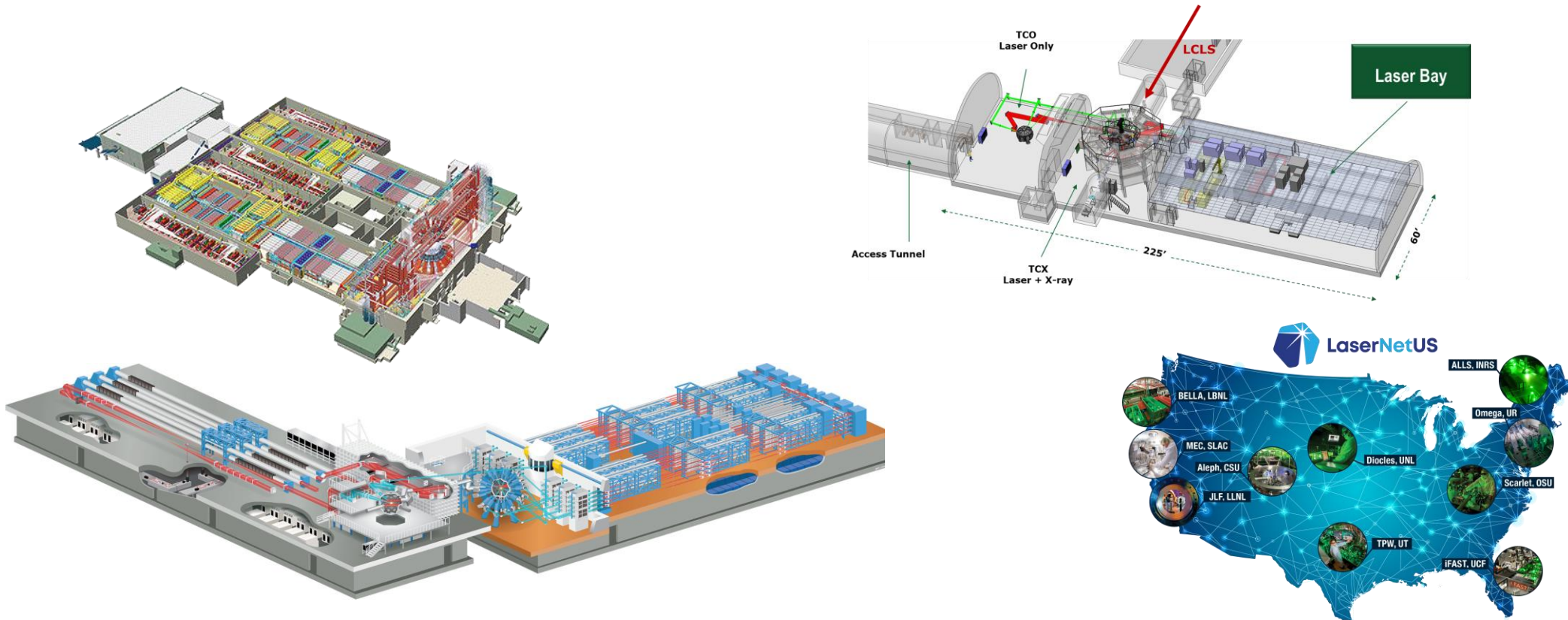


Lasers



IFE Basic Research Needs Workshop Charge (2)

- Assess enabling science and technologies common to ICF and IFE and define a set of proposed priority research opportunities that address the research and R&D challenges unique to IFE, along with evaluation criteria to assess ongoing progress in an IFE technology development program.



IFE Basic Research Needs Workshop Charge (3)

- **Assess the maturity and potential of the various IFE concepts toward a path to a viable IFE fusion power plant. Use Technology Readiness Level (TRL) methodology to guide the R&D demonstration of ignition and reactor-level gain for each concept:**
 - Manufacturing and mass production of reactor-compatible targets
 - Driver technology at reactor-compatible energy, efficiency, and repetition rate
 - Chamber design and first wall materials
 -

D.T. Goodin *et al*

Table 1. Cost estimates for laser fusion, HIF and ZFE.

IFE concept	Target	Installed capital cost (M\$)	Annual operation cost (M\$)	Target supply rate (Hz)	Cost per target (\$)	Percentage of electricity value
Laser fusion	Direct drive capsule	100	19	6	0.17	6
HIF	Distributed radiator hohlraum with CH capsule	304	39	6	0.41	14
ZFE	Dynamic hohlraum with Be capsule	325	50	1	2.82 ^a	12.5

^a Preliminary datum, does not include cost of RTL, which is necessary for ZFE.



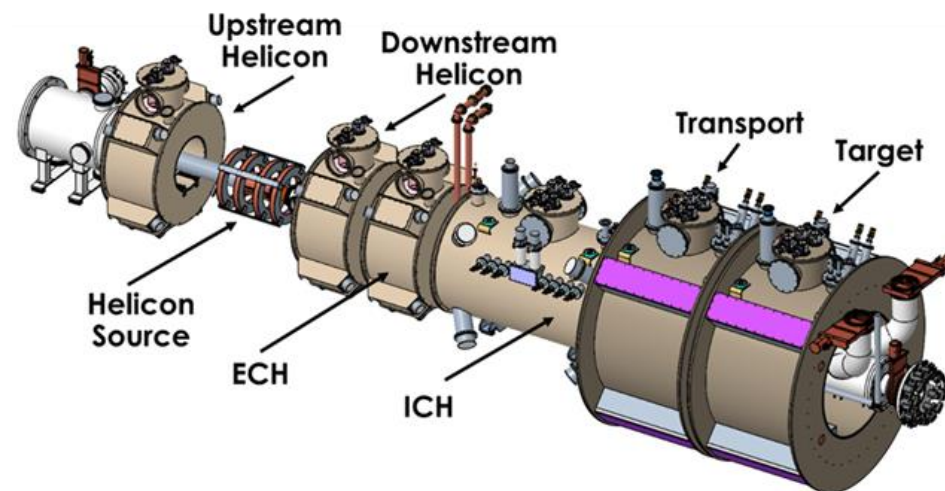
Rendering of the LIFE fusion power plant

An IFE program should find solutions to relevant S&T problems

IFE Basic Research Needs Workshop Charge (4)

- Identify MFE efforts in the United States and abroad that could be leveraged to advance IFE. (e.g., blanket, structural, and plasma-facing materials development, deuterium-tritium fuel cycle processing, remote handling technology, safety analysis tools, waste stream management, modeling, etc.), and identify where there are substantive differences in these systems that require IFE-specific development.

Material Plasma
Exposure Experiment





IFE Basic Research Needs Workshop Charge (5)

- **Assess the role of the private sector, including public-private partnerships in a National IFE Program.**

INFUSE Innovation Network
for Fusion Energy

What Is INFUSE? Topic Areas Meetings Library Submission

First round 2022 RFA call open

The first round of RFA submissions for 2022 opened on January 03, 2022 and will close on February 11, 2022 at 5:00 pm EST. RFAs are being sought in the 5 topical areas covered by INFUSE and are open to partnering with any of the 17 DOE national laboratories or accredited U.S. universities engaged in fusion research. The 2022 RFA Opportunity Announcement can be found [here](#) or in the Library. U.S. companies can submit an RFA following the submission process outlined under the submission [tab](#).

Helpful Links

- [FES HomePage](#)
- [Oak Ridge National Laboratory](#)
- [Princeton Plasma Physics Laboratory](#)
- [Virtual Laboratory for Technology](#)



What are the deliverables?

- **The BRN is expected to provide FES with a set of priority research opportunities (PROs) that can inform future research efforts in IFE and build a community of next-generation researchers in this area.**
- **The findings of this BRN will be summarized in a report that should be submitted to FES within four months after the meeting.**



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PROGRESSING OUR SCIENCE

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